HHS Public Access

Author manuscript

Int J Obes (Lond). Author manuscript; available in PMC 2015 April 23.

Published in final edited form as:

Int J Obes (Lond). 2013 October ; 37(10): 1344–1351. doi:10.1038/ijo.2013.128.

Maternal prepregnancy weight status and associations with children's development and disabilities at kindergarten

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Abstract

OBJECTIVE—Obesity is prevalent among women of reproductive age, and developmental disabilities in children continue to increase. We examined associations between mother's prepregnancy body mass index (BMI) and physical and developmental disabilities, and objective measures of reading and math skills and fine and gross motor function in children.

METHODS—We used the Early Childhood Longitudinal Study-Birth Cohort (ECLS-B; n = 5200), a cohort of children born in 2001 and followed until kindergarten. Children were classified according to maternal prepregnancy BMI (in kg per m^2): underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9), obese class I (BMI 30.0–34.9) and obese class II/III (BMI ≥35.0). Parent reports of doctor-diagnosed disabilities were collected up to kindergarten and classified as learning and behavioral or physical. Children's reading and math and fine and gross motor function were assessed at kindergarten according to standardized tests. Linear and modified logistic regression models were adjusted for maternal sociodemographic variables, family enrichment variables, and children's sex, age and year of kindergarten entry. Additional adjustment for current child BMI was performed in separate models. All data are weighted to be nationally representative of the children born in 2001.

RESULTS—Compared with children of normal-weight mothers, children born to obese class II/III mothers had an increased risk of learning or behavioral (risk ratio 1.67; 95% confidence interval 1.27, 2.21)), but not physical disabilities (risk ratio 0.57; 95% confidence interval 0.27, 1.22). Gross (P<0.001), but not fine (P = 0.06) motor function was significantly associated with maternal BMI, but gross motor function was attenuated after adjustment for current child BMI (P

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Supplementary Information accompanies this paper on International Journal of Obesity website (http://www.nature.com/ijo)

= 0.05). Children's reading scores (P = 0.01) but not math scores (P = 0.11) were significantly associated with maternal BMI.

CONCLUSIONS—In this nationally representative US cohort, children born to severely obese mothers had an increased risk for diagnosed learning and behavioral but not physical disabilities by kindergarten.

Keywords

pregnancy; development; disabilities; cognitive function

INTRODUCTION

Obesity is associated with metabolic changes including systemic chronic inflammation, increased oxidative stress and hyperglycemia.[1] In 2009, ~1 in 5 pregnant women were obese when they became pregnant.[2] Metabolic changes, such as increased insulin resistance in the second and third trimesters, are part of a healthy pregnancy;[3] however, when augmented with the metabolic state associated with prepregnancy obesity, these changes may be exacerbated, such that the metabolic and immune state of the mother may have profound effects on the developing fetus.[4,5] For example, it is well observed that maternal obesity is associated with neural tube defects.[6] Similarly, increased oxidative stress associated with obesity may negatively impact the developing fetal brain, leading to later disabilities, including autism spectrum disorders.[7] Because there are complex interactions between the maternal immune system and the fetal developing central nervous system, alterations in the balance of the intrauterine immune system may cause neurodevelopmental damage, leading to the pathogenesis of cognitive disabilities and adverse behavioral outcomes in offspring.[8–11] Given these potential biological mechanisms, there is increasing interest in epidemiologic research related to maternal prepregnancy weight and child developmental outcomes.[12] To date, most research is from European cohorts,[13–17] where the prevalence of prepregnancy obesity is lower than in the United States, or from smaller[18,19] or less generalizable US cohorts limited to a single state.[20,21] Although most, but not all,[13] have observed an adverse effect of maternal obesity, it remains unclear if modest differences observed using cognitive assessment batteries[17,19,22] translate to clinically relevant outcomes in children.

Using a nationally representative US cohort, we previously reported an increased risk for delayed mental development at age 2 years, assessed using a validated standardized assessment, among children born to mothers who were underweight or severely obese before pregnancy.[23] To extend this prior research, we investigated the association between maternal prepregnancy body mass index (BMI) and children's development at kindergarten. In the present analysis, children's developmental outcomes included diagnosed physical and developmental disabilities, as well as reading and math skills, and fine and gross motor function that were objectively measured using standardized assessments.

MATERIALS AND METHODS

Data source

We utilized data from the US Department of Education's Early Childhood Longitudinal Study-Birth Cohort (ECLS-B), a nationally representative cohort of children born in 2001 who were followed until kindergarten entry. In order to protect participant identity, per our data agreement, all sample sizes reported in the paper are rounded to the nearest 50 and percentages are reported as weighted population estimates. This analysis was reviewed by a human subjects coordinator at the Centers for Disease Control and Prevention (CDC) and determined to be research not involving human subjects.

The ECLS-B participants were selected using birth certificates from the Vital Statistics System of the National Center for Health Statistics and included an oversample of twins, select racial–ethnic groups and infants born weighing <2500 g. Participant data were collected across five waves. At wave one, 10 700 participants, ~9 months of age, were enrolled. Waves two and three occurred at approximately ages 2 and 4 years, respectively. Mostly because of birthdate cut-points for kindergarten enrollment, not all children in the ECLS-B started kindergarten in the same school year. For most of the sample (73%), wave four corresponded with entry into kindergarten during the 2006–2007 school year. Wave five occurred only for children who enrolled in kindergarten for the first time in 2007–2008. At kindergarten entry, on average children were 68 months of age (interquartile range 65–72; range 57–85 months).

Maternal prepregnancy BMI

At wave one, biological mothers of participants were asked their height and prepregnancy weight. Prepregnancy BMI (in kg per m^2) was calculated and categorized as: underweight (BMI <18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25.0–29.9), obese class I (BMI 30.0–34.9) and obese classes II and III (BMI ≥35.0).[24]

Children's Bayley Scales of Infant Development-II

At wave two, children's mental and motor development was assessed using a shortened validated version of the Bayley Scales of Infant Development-II (BSID-II).[25] ECLS-B provided age-standardized T-scores (mean 50, s.d. 10), normalized to the ECLS-B population.

Children's disability diagnoses

At select waves, the parent respondent or primary caregiver reported if their child had been previously diagnosed by a doctor with select disabilities (Supplementary Table 1). We classified children as having a learning or behavioral disability if they were ever diagnosed with autism or pervasive development disorder, oppositional defiant disorder, attention deficit hyperactivity disorder, stuttering, intellectual disability or another developmental delay. Because stuttering can be considered a communication disorder, we also examined learning and behavioral disabilities independent of stuttering. Children were classified as having a physical disability if they were ever diagnosed with hearing loss, blindness, epilepsy or a motor disability such as cerebral palsy. We also examined the physical

disability composite excluding children with epilepsy. Because of the limited sample size and the rarity of many of the conditions, we were restricted from analyzing the individual disabilities separately.

Children's reading and mathematics skills

Children's early reading and math skills were assessed at kindergarten by certified fieldworkers according to standardized tests based on components of instruments used in other large-scale studies.[26] Using these tests, ECLS-B generated scales scores for reading and math skills.[26] We generated standardized reading and math *Z*-scores from the scale scores developed by ECLS-B.

Children's fine and gross motor function

At kindergarten, children's fine and gross motor skills were assessed using components of standard instruments administered by certified field-workers.[26] To assess fine motor function, children were asked to build a gate using blocks and to copy four geometric shapes. Each drawing was scored as pass/fail by certified coders. We classified children who did not successfully build the gate and pass at least half of the shape assessments with low fine motor function. Gross motor skills were assessed using various physical tasks including jumping horizontally, balancing, hopping, skipping, walking backwards and catching. The distance jumped was compared with all children in the cohort and if the distance was less than the 10th percentile we classified children as failing the jumping assessment. Fieldworkers classified all other tasks as pass/fail. Children who did not complete a task because of a physical limitation ($n<50$) were classified as having failed the assessment. We summed the number of gross motor tasks failed and classified children who failed more than half with low gross motor function.

Additional variables

Mother's age at delivery, race–ethnicity, parity, marital status, schooling and smoking history during pregnancy as well as children's sex were obtained from the child's birth certificates. At wave three, the number of children's books in the house (≤20, 21–99, ≥100), whether the parents read to the child everyday (yes/no) and the total hours of television viewed by the child in a typical weekday (>2 h, yes/no) were assessed and used as indicators of learning enrichment. Family poverty status at kindergarten was determined by household income and size and classified according to the federal poverty limit (<130, 130 to <185 and ≥185%).[27] At kindergarten, children's height and weight were measured at least twice according to a standard protocol. Children were classified according to sex and age-specific BMI percentiles as underweight (<5), normal weight (5 to <85), overweight (85 to <95) or obese (≥95).[28]

Analysis and study sample

We limited our analysis to singletons born without major congenital anomalies. Of the 8850 eligible participants, 2150 were lost to follow-up by kindergarten entry and a random sample of 1150 participants was not included at kindergarten because of budgetary restraints, leaving 5550 participants. We performed a complete-subject analysis and excluded

participants lacking exposure or covariate data (n = 300), resulting in 5200 children with disability data, weighted to be representative of ~3.5 million singleton US children born in 2001.

In a previous ECLS-B analysis, we examined mental and motor development at age 2 years by prepregnancy BMI.[23] To assess the effect of attrition from our previous study to the present sample, we compared the characteristics of the available sample to those excluded. Many demographics of the current sample differed from those excluded; however, no differences were observed in prepregnancy BMI (Supplementary Table 2). To further verify that attrition and missing data did not bias the current sample, we reexamined the association between neurodevelopment at age 2 years and prepregnancy BMI using the present sample available at kindergarten and found similar effect sizes as in our previous analysis[23] (data not shown).

For the current study, a subset of children did not complete reading and math assessments at kindergarten and thus were excluded from the reading and math analyses (n = 150). Compared with the remaining sample (n = 5100), those excluded differed with regard to maternal race–ethnicity (P = 0.02), had lower poverty status (P = 0.02) and were more likely to have a learning or behavioral (39.5% vs 12.4%; P<0.001) or physical disability (10.0% vs 4.6%; P = 0.01) (data not shown). Similarly, a subset of children did not complete the motor assessments (n = 450) and were excluded from the motor analyses. Compared with the remaining sample (n = 4750), those excluded had mothers with less schooling (P = 0.02), lower poverty status (P<0.001) and were more likely to have a learning or behavioral (27.3% vs 11.8%; P<0.001) or physical disability (8.6% vs 4.4%; P = 0.003) (data not shown).

As a means of verifying maternal report of disability diagnoses, we examined all objectively measured indicators of children's development (mental and motor BSID-II T-scores at age 2 years, reading and math Z-scores at kindergarten and motor function at kindergarten) by disability diagnoses.

We examined the independent associations between maternal prepregnancy BMI and children's disability diagnoses and objective measures of development. We used linear regression for continuous outcomes and logistic models modified to calculate model-adjusted risk ratios for dichotomous outcomes.[29] We used a directed acyclic graph to inform decisions as to which variables to include in the models (Figure 1).[30] We made the assumption that an unobserved latent ‘lifestyle’ variable influenced both mother's prepregnancy BMI and children's development (through family enrichment). Based on the latter assumption, the minimally sufficient set of variables required to assess the total effect of prepregnancy BMI on development was determined to be demographics, smoking and enrichment.[31] Because the directionality of the relationship between prepregnancy BMI and enrichment is truly unknown, and contrary to our assumptions, enrichment could be influenced by prepregnancy BMI, we performed a sensitivity analysis in which we did not adjust for enrichment, as in this case enrichment would be on the causal pathway. No models included mediators of the relationship between prepregnancy BMI and development, that is, gestational weight gain, gestational diabetes or hypertension and fetal growth (shown

in Figure 1 with dashed lines).[32] Furthermore, although potentially also on the causal pathway, we performed a sensitivity analysis adjusted for children's weight status at kindergarten entry, as these relationships are complex and children of obese mothers are more likely to be obese and obesity in children has been shown to correlate with children's developmental status. All models were adjusted for children's age at kindergarten entry. No evidence of multicollinearity between variables was detected for any model. Approximately 4% of mothers were <18 years old and because the use of adult BMI-classification cut-points may have misclassified adolescents mothers,[33] we performed sensitivity analyses limited to children of mothers aged ≥18 years.

We used Statistical Analysis Software (SAS) version 9.2 (Cary, NC, USA) with SAS-Callable SUDAAN version 10.0.1 (Research Triangle Park, NC, USA). The *P*-values of <0.05 were considered to be indicative of significant differences. All analyses were weighted using ECLS-B survey weights to account for subject lost to follow-up and the complex sample survey design. Taylor Series approximations were used to estimate standard errors.

RESULTS

By kindergarten entry, 16.0% of children had been diagnosed with a disability. Specifically, 13.0% of children had a learning or behavioral disability, of which 25.0% had more than one learning or behavioral disability. Overall, 4.7% of children had a physical disability, of which 8.3% had more than one physical disability. As a means to verify maternal report of children's disabilities, we evaluated the objective measures of development that were collected independent of the maternal report (that is, Bayley Scales of Infant Development-II, reading and math scores and motor function) by children's disability status. Compared with those with no disabilities, children with any disability had significantly lower mental and motor development T-scores, lower reading and math *Z*-scores and a higher prevalence of low fine and gross motor function ($P<0.001$ for all comparisons; Table 1).

Before pregnancy, 5.3% of mothers were underweight, 54.9% were normal weight, 25.0% were overweight, 8.6% were class I obese and 6.2% were class II or III obese. All maternal characteristics examined varied by prepregnancy BMI (Table 2). Underweight mothers tended to be younger, less likely to be married, have less schooling, have smoked during their pregnancy and live in poverty compared with normal-weight mothers. Obese class II or III mothers also were less likely to be married, have at least 16 years of schooling compared with normal-weight mothers and the greatest proportion of obese class II or III mothers lived below 130% of the federal poverty limit. Learning enrichment-related variables also tended to correlate with maternal pre-pregnancy BMI status, such that children of normal-weight mothers were the most likely to be read to daily and watch <2 h of TV on weekdays. Children's weight status at kindergarten was strongly associated with their mother's prepregnancy BMI status. Although 76.3% of children of underweight mothers were considered normal weight at kindergarten, only 46.1% of children born to class II or III obese mothers fell into this category. Class II or III obese mothers had the greatest proportion of obese children (37.6%).

In models adjusted for maternal demographics, smoking and enrichment, prepregnancy BMI was significantly associated with learning or behavioral disabilities in children with the greatest risk among children of class II and III obese mothers (Table 3). This association remained when stuttering was excluded from the composite and when adjusted for current child weight status. A greater proportion of children of underweight mothers had a physical disability compared with children of normal-weight mothers and this association was strengthened when epilepsy was excluded from the composite, although overall the global association was not significant ($P = 0.32$). When also adjusted for current child weight status, there was suggestion of an increased risk of physical disabilities associated with maternal class II and III obesity; however, this was attenuated when epilepsy was removed from the composite, and the overall association was nonsignificant ($P = 0.11$). Comparatively, children of class II and III obese mothers had an increased risk for low fine and gross motor development, but when adjusted for current child weight status, the associations between maternal prepregnancy BMI and children's motor development, particularly gross motor, were attenuated (Table 4). There was a significant association between maternal prepregnancy BMI and children's reading scores, but not math scores (Table 5). All associations were similar in sensitivity analyses in which enrichment variables were not included or when limited to children born to nonadolescent mothers (data not shown).

DISCUSSION

Using a nationally representative cohort of US children born in 2001, we observed an increased risk of learning and behavioral disabilities in children born to mothers who were severely (class II or III) obese at the start of their pregnancy in comparison with mothers who were normal weight. In addition, children's reading scores were significantly associated with maternal pregnancy BMI. We did not, however, observe a significant association between prepregnancy BMI and diagnosis of physical disabilities in children and the associations with motor function were attenuated after including current child BMI in the model. These findings are consistent with our previous study[23] in which we observed an increased risk for delayed mental function, but not motor function, at 2 years of age in children born to severely obese mothers, and demonstrate that the association persists to kindergarten age and coincides with an increased risk of clinical outcomes of learning and behavioral disabilities.

Similar to other national estimates,[34] 13% of children in our study had a learning or behavioral disability diagnosis, potentially including attention deficit hyperactivity disorder, autism or pervasive development disorder, oppositional defiant disorder, intellectual disability, stuttering or another developmental delay. Among children whose mothers were severely obese at the start of their pregnancy, the prevalence of learning or behavioral disabilities at kindergarten was 20.4%, in comparison with only 11.9% of children born to normal-weight mothers, leading to a 67% increased risk of diagnosis. This association was maintained after removing stuttering from the composite, as stuttering is also considered a communication disorder. Because of the rarity of these conditions and sample size, we were precluded from estimating associations with individual conditions; therefore, future investigations disentangling the risks by specific conditions may be important. Nonetheless,

research suggests that considerable overlap exists between these conditions and they do not typically occur in isolation.[35] Our study supports this notion, as approximately a quarter of children with learning or behavioral disability had more than one of the selected conditions.

Our finding that maternal obesity may be a risk factor for learning and behavioral disabilities in children is consistent with previous literature. With the exception of a study that combined overweight and obesity and observed inconsistent findings,[13] all other studies have reported an adverse association between prepregnancy obesity and lower child cognitive scores,[17,19,22,23] intellectual disability,[14,21] attention deficit hyperactivity disorder symptoms[15,16,18] and autism in children.[20] Our study builds on this literature by utilizing a population-based US cohort, examining both disabilities and objective measures of development, and severe obesity separately from class I obesity. Notably, we found the strongest risk among children born to severely obese mothers. In contrast to our previous study of children at age 2 years,[23] we did not observe an increased risk of learning or behavioral disabilities among children born to underweight mothers. It is plausible that any deleterious effect of prepregnancy underweight dissipated by kindergarten, as mental development scores at age 2 years in children born to underweight mothers were not as low as in children of severely obese mothers.

Approximately 15% of mothers in our sample were obese at the start of their pregnancy, of whom almost half were severely obese. Severely obese mothers are known to have the greatest risk for maternal and neonatal pregnancy complications, and we observed that their children also have an increased risk for learning or behavioral disabilities.[36] It is hypothesized that the inflammatory intrauterine environment associated with maternal obesity interrupts the fetal central nervous system development and makes it more susceptible to other environmental insults by disrupting the blood brain barrier, all potentially leading to the increased risk for disabilities.[7–11] Our findings are independent of sociodemographic factors and select learning and enrichment variables. Factors such as maternal chronic diseases or weight gain or loss during pregnancy may act downstream of prepregnancy obesity, further affecting the intrauterine environment and leading to neurodevelopmental damage and the pathogenesis of cognitive disabilities and adverse behavioral outcomes in offspring.[8–10] Alternatively, specific characteristics of maternal diet associated with obesity may also be important.[37] Furthermore, these conditions, in addition to obesity, may also adversely affect fetal growth or the length of gestation,[33] and thus potentially affect neurodevelopment.[38] In this analysis we did not adjust for these mediating factors,[32] and thus future studies focused on clarifying the underlying mechanism will be important to fully understand the implications of our findings and the potential relevant time frame for interventions. Some studies have included pregnancy weight gain in models related to prepregnancy BMI and observed no association.[21] Others have specifically examined weight gain as the exposure. One study of predominantly nonobese mothers observed no association when accounting for familial factors.[39]Another study observed that weight gain both below and above recommendations was associated with lower academic achievement at 16 years of age, and although they found that the association may differ according to the timing of weight gain, they did not examine the associations in obese mothers separately from overweight mothers.[40]

The mechanism by which maternal BMI is associated with child development may alternatively be driven through an increased risk for obesity in the children. For example, the observed association may be due, in part, to poor motor development in obese children, residual confounding due to external factors that could potentially cause obesity and developmental delays, or poor motor function may precede child obesity.[41] We adjusted for children's weight status at kindergarten entry in a separate model, as the relationship is likely complex and it is unclear whether it is a confounder or mediator of the association, and this may vary according to specific conditions within the composites. The estimates related to learning or behavioral disabilities were unaffected by the additional adjustment, but we observed a slightly stronger association with physical disabilities such that maternal underweight was associated with an increased risk, and class II and III obesity was associated with a reduced risk, but the overall association with maternal BMI remained nonsignificant. When epilepsy was removed from the composite, the association with class II and III obesity was attenuated, suggesting that some of the association may have been because of a reduced risk for epilepsy, and this should be explored further using more detailed data on epilepsy. Comparatively, although the overall association with gross motor development was attenuated when adjusted for current child weight status, severe obesity was still associated with an increased risk of low gross motor function compared with children of normal-weight mothers, highlighting that these children may have a particularly higher risk than their peers.

Our study has important strengths and limitations. Although we used a large population-based cohort, generalizable to US children born in 2001, as with most longitudinal cohorts, there was attrition in the sample that could potentially lead to bias in our results; however, much of the loss of sample was because of a random sample of children who were not followed-up to kindergarten because of budgetary restraints. To help inform if this loss to follow-up biased our results, we reconfirmed our prior findings[23] at age 2 years specifically among the sample who had data at kindergarten. Prepregnancy BMI was calculated from self-reported height and prepregnancy weight, which may result in an underestimate of BMI among heavier mothers and an overestimate among lighter mothers;[42] however, a previous study found that some short-term obstetric outcomes were robust to misclassification in prepregnancy BMI status.[42] Furthermore, any reporting bias in prepregnancy weight and height is independent of our outcomes, which occurred much later. Although some of children's developmental outcomes were based on standardized objective assessments, children's disability status was obtained by maternal report of doctor diagnoses. Out of concern that some parents may have misreported diagnoses, we examined objective measures of children developmental status according to each disability. We found that children with disabilities had lower neurodevelopment scores at age 2 years, lower reading and math scores and a higher prevalence of low motor function, suggesting some validity in the maternal report of children's disabilities. We assessed the risk for ever having been diagnosed; however, some of these conditions are transient and may have been resolved by kindergarten, and therefore our results do not necessarily represent current disabilities among kindergarteners. Finally, our findings were based on models with covariates chosen *a priori* informed by the directed acyclic graph.

Our findings further raise concern that prepregnancy obesity may have long-term deleterious effects on children's development. This is particularly concerning given the high proportion of women who are obese at the start of their pregnancy[2] and the increase in developmental disabilities in children.[34] Although the specific mechanisms of the observed association remain unclear, there is substantive support in the literature suggesting that intrauterine changes associated with obesity may cause neurological damage to the developing fetus.[7–11] Maternal obesity should be considered in future analyses as a potential risk factor for developmental delays in children. The most widespread approach for addressing this risk factor may be through greater focus on pre- and inter-conception care that helps women maintain or achieve a healthy weight before pregnancy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGEMENTS

This research was performed in part under an appointment to the Centers for Disease Control and Prevention, administered by the Oak Ridge Institute for Science and Education under contract number DE-AC05–06OR23100 between the US Department of Energy and Oak Ridge Associated Universities.

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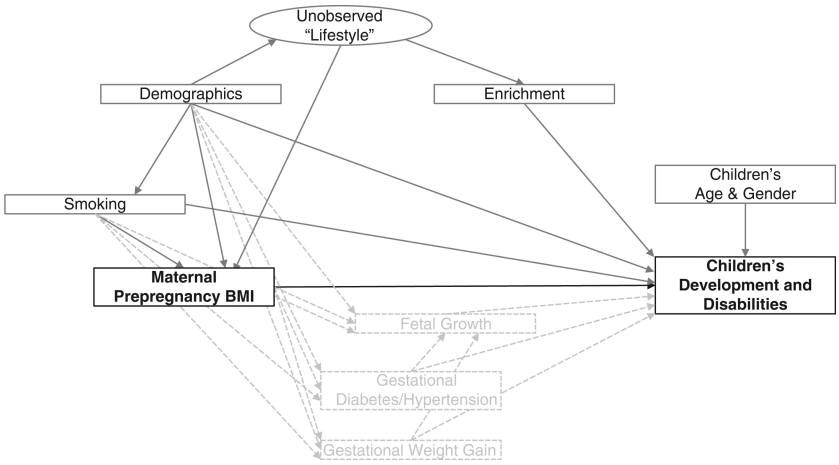

Figure 1.

Directed acyclic graph (DAG) describing the relationship between maternal prepregnancy BMI and children's development and disabilities. Dashed lines represent paths associated with variables on the causal pathway and were not included in adjusted models.

Table 1

Objective developmental assessments according to child disabilities, Early Childhood Longitudinal Study-Birth Cohort, United States, 2001-2007

	%[a]	Bayley Scales of Infant Development-II at 2 years of age, n = 4750		Reading and math at kindergarten entry, n = 5100		Motor function at kindergarten entry, n = 4650	
		Mental development, T-score Mean (95% CI)	Motor development, T-score Mean (95% CI)	Reading, Z-score Mean (95% CI)	Math, Z-score Mean (95% CI)	Fine motor low function[b] % (95% CI)	Gross motor low function[c] % (95% CI)
No disability	84.0	51.4 (51.0, 52.0)	50.8 (50.2, 51.4)	0.06 (0.00, 0.11)	0.07 (0.02, 0.12)	4.2 (3.3, 5.1)	6.5 (5.3, 7.7)
Any disability	16.0	45.7 (44.7, 46.8)	47.9 (46.7, 49.0)	–0.30 (–0.40, –0.20)	–0.39 (–0.49, –0.29)	10.9 (7.6, 14.1)	18.2 (14.5, 21.9)
Learning or behavioral disability[d]	13.0	45.3 (44.2, 46.4)	47.7 (46.4, 49.0)	–0.37 (–0.48, –0.27)	–0.46 (–0.57, –0.34)	12.3 (8.6, 16.0)	21.4 (17.0, 25.9)
ADHD	2.9	42.8 (40.5, 45.1)	47.7 (44.9, 50.5)	–0.78 (–1.00, –0.56)	–0.84 (–1.05, –0.63)	17.8 (8.8, 26.8)	26.7 (15.5, 37.8)
Autism or PDD	1.3	33.5 (29.2, 37.7)	37.7 (33.9, 41.5)	–0.21 (–0.65, 0.22)	–0.38 (–0.81, 0.05)	25.0 (5.5, 44.4)	50.1 (30.0, 70.1)
ODD	0.7	49.0 (45.2, 52.8)	50.2 (46.0, 54.4)	–0.27 (–0.66, 0.11)	–0.23 (–0.68, 0.21)	23.3 (0.00, 49.6)	21.8 (0.00, 47.6)
Intellectual disability	0.6	41.2 (36.4, 45.9)	38.2 (30.1, 46.2)	–0.65 (–1.19, –0.11)	–0.88 (–1.69, –0.06)	44.5 (9.2, 79.8)	39.8 (3.1, 76.4)
Stutter	6.7	47.7 (46.3, 49.2)	49.6 (48.2, 51.0)	–0.31 (–0.45, –0.17)	–0.38 (–0.54, –0.21)	12.4 (7.6, 17.2)	15.5 (10.0, 21.1)
Other developmental delay	5.0	40.6 (38.3, 42.9)	43.7 (41.0, 46.3)	–0.39 (–0.56, –0.22)	–0.57 (–0.78, –0.36)	15.5 (8.6, 22.5)	33.1 (23.5, 42.8)
Physical disability[e]	4.7	45.4 (43.6, 47.2)	46.1 (43.8, 48.5)	–0.28 (–0.48, –0.08)	–0.37 (–0.58, –0.16)	8.8 (3.2, 14.3)	16.4 (9.3, 23.5)
Mobility disability	0.8	42.1 (38.5, 45.6)	38.7 (31.6, 45.7)	–0.47 (–1.09, 0.14)	–0.65 (–1.48, 0.17)	13.2 (0.00, 28.8)	28.3 (5.5, 51.0)
Hearing loss	2.5	44.6 (42.5, 46.6)	46.3 (43.1, 49.4)	–0.24 (–0.50, 0.03)	–0.33 (–0.59, –0.07)	7.3 (0.00, 14.7)	15.3 (6.3, 24.3)
Blindness	0.3	46.3 (35.5, 57.1)	48.4 (39.4, 57.4)	–0.85 (–1.83, 0.13)	–0.99 (–2.53, 0.56)	43.2 (0.00, 87.9)	18.8 (0.0, 50.2)
Epilepsy	1.6	46.8 (44.1, 49.4)	48.2 (44.9, 51.4)	–0.33 (–0.67, 0.00)	–0.35 (–0.68, –0.03)	7.9 (0.00, 16.0)	16.6 (4.7, 28.4)

Abbreviations: ADHD, attention deficit hyperactivity disorder; CI, confidence interval; ODD, oppositional defiant disorder; PDD, pervasive development disorder.

[a] Percentages of disabilities based on the overall sample (n = 5200).

[b] Children who did not successfully pass the gate building assessment and at least half of the copy shape assessments were classified as having low fine motor function.

[c] Children who passed less than half of the gross motor tasks were classified as having low gross motor function.

[d] Learning or behavioral disability classified as ever diagnosed with ADHD, autism or PDD, ODD, intellectual disability, stuttering or other developmental delay.

[e] Physical disability classified as ever diagnosed with hearing loss, blindness, epilepsy or mobility disability such as cerebral palsy.

Table 2

Maternal and child characteristics of the study sample according to maternal prepregnancy weight status, Early Childhood Longitudinal Study-Birth Cohort, United States, 2001-2007

	Underweight, n = 350, %[a]	Normal weight, n = 2950, %[a]	Overweight, n = 1150, %[a]	Obese class I, n = 450, %[a]	Obese class II and III, n = 300 %[a]	P-value
Maternal variables						
Age, years						< 0.001
15-19	24.5	12.8	7.4	6.7	5.8	
20-24	30.6	23.9	27.1	24.8	25.9	
25-29	17.6	27.9	24.9	30.5	26.7	
30-34	22.1	22.2	25.2	23.9	28.6	
35-50	5.1	13.2	15.4	14.0	13.0	
Race-ethnicity						< 0.001
White, non-Hispanic	62.0	63.5	61.7	52.9	54.3	
Black, non-Hispanic	12.7	13.2	13.7	20.9	25.4	
Hispanic	16.6	18.2	22.3	24.1	18.76	
Asian/Pacific Islander/Native Hawaiian	7.9	4.5	1.6	1.0	0.5	
American Indian/Alaskan Native	0.9	0.7	0.7	1.1	1.12	
Married	60.3	69.3	70.0	63.7	62.46	0.02
Schooling, years						< 0.001
<12	26.9	19.6	19.9	19.7	22.8	
12	41.2	29.0	32.9	37.0	36.6	
13-15	18.7	21.2	23.3	25.8	28.1	
≥16	13.2	30.3	23.9	17.5	12.5	
Primiparous	52.8	44.9	37.3	31.2	33.7	< 0.001
Smoked during past 3 months of pregnancy	24.4	10.9	8.5	14.8	12.9	< 0.001
Household poverty						<0.001
<130%	37.0	27.3	33.0	37.7	40.2	
130 to < 185%	16.0	11.8	15.5	14.8	12.9	
≥185%	46.9	60.9	51.5	47.5	46.9	
Enrichment variables						
Read books to child daily	31.8	43.0	35.4	35.7	32.1	< 0.001
Child watched TV > 2 h per day	62.9	58.1	60.4	68.4	71.6	< 0.001
Number of books in household						
≤20	33.2	25.4	30.2	32.6	29.5	0.11
21-99	39.4	41.2	40.1	41.0	42.0	
≥100	27.4	33.4	29.6	26.5	28.6	
Children's variables						
Weight status at kindergarten						< 0.001
Underweight	3.8	1.8	1.5	1.7	0.9	
Normal weight	76.3	69.1	58.9	54.8	46.1	

	Underweight, n = 350, %[a]	**Normal weight, n = 2950, %[a]**	**Overweight, n = 1150, %[a]**	**Obese class I, n = 450, %[a]**	**Obese class II and III, n = 300 %[a]**	**P-value**
Overweight	8.2	17.0	20.5	20.2	16.2	
Obese	1.8	12.1	19.1	23.3	37.6	
Learning or behavioral disability[b]	14.6	11.9	12.5	14.7	20.4	0.01
Learning or behavioral disability *excluding* stuttering	8.4	6.9	6.6	7.7	12.7	0.01
Physical disability[c]	6.2	4.5	5.6	3.7	2.9	0.34
Physical disability *excluding* epilepsy	5.6	2.8	4.2	3.1	2.6	0.20
Low fine motor	4.6	6.0	6.1	9.4	8.9	0.08
Low gross motor	11.1	7.0	10.6	9.0	14.8	0.001

[a]Presented as unweighted sample size rounded to the nearest 50 and weighted % per data agreement with the Department of Education. Percentages may not add to 100 because of rounding.

[b]Learning or behavioral disability classified as ever diagnosed with attention deficit hyperactivity disorder (ADHD), autism or pervasive development disorder (PDD), oppositional defiant disorder (ODD), intellectual disability, stuttering or other developmental delay.

[c]Physical disability classified as ever diagnosed with hearing loss, blindness, epilepsy or mobility disability such as cerebral palsy.

Table 3

Adjusted associations between maternal prepregnancy weight status and child disabilities, Early Childhood Longitudinal Study-Birth Cohort, United States, 2001-2007

Outcomes	Underweight (n = 350) RR (95% CI)	Normal weight (n = 2950) RR (95% CI)	Overweight (n = 1150) RR (95% CI)	Obese class I (n = 450) RR (95% CI)	Obese class II and III (n = 300) RR (95% CI)	P-value[a]
Adjusted for demographics, smoking and enrichment [b]						
Learning or behavioral disability[c]	1.12 (0.73, 1.70)	1.00 (Referent)	1.05 (0.83, 1.33)	1.23 (0.91, 1.66)	1.67 (1.27, 2.21)	0.007
Learning or behavioral disability *excluding* stuttering	1.11 (0.70, 1.78)	1.00 (Referent)	0.90 (0.68, 1.21)	1.12 (0.80, 1.57)	1.79 (1.20, 2.66)	0.03
Physical disability[d]	1.35 (0.73, 2.50)	1.00 (Referent)	1.17 (0.76, 1.80)	0.76 (0.43, 1.34)	0.57 (0.27, 1.22)	0.32
Physical disability *excluding* epilepsy	2.04 (1.04, 3.98)	1.00 (Referent)	1.42 (0.82, 2.46)	1.01 (0.49, 2.10)	0.79 (0.33, 1.90)	0.23
Adjusted for demographics, smoking, enrichment and current child weight status [e]						
Learning or behavioral disability[c]	1.08 (0.71, 0.65)	1.00 (Referent)	0.93 (072, 1.19)	1.24 (0.91, 1.70)	1.65 (1.24, 2.18)	0.001
Learning or behavioral disability *excluding* stuttering	1.05 (0.65, 1.71)	1.00 (Referent)	0.77 (0.57, 1.05)	1.12 (0.78, 1.60)	1.73 (1.11, 2.68)	0.02
Physical disability[d]	1.34 (0.71, 2.53)	1.00 (Referent)	1.07 (0.66, 1.72)	0.72 (0.37, 1.40)	0.34 (0.12, 0.92)	0.12
Physical disability *excluding* epilepsy	2.11 (1.06, 4.19)	1.00 (Referent)	1.26 (0.69, 2.30)	1.05 (0.51, 2.18)	0.50 (0.17, 1.48)	0.11

Abbreviations: CI, confidence interval; RR, risk ratio. All models adjusted for child's sex, age at final assessment, year of kindergarten entry, TV hours, number of children's books in the house and typical number of nights parent reads to the child, as well as maternal age, race-ethnicity, parity, schooling, poverty and smoking during pregnancy.

[a] *P* for the overall adjusted association with prepregnancy weight status.

[b] Models adjusted for child's sex, age at final assessment, year of kindergarten entry, TV hours, number of children's books in the house and typical number of nights parent reads to the child, as well as maternal age, race-ethnicity, parity, schooling, poverty and smoking during pregnancy.

[c] Learning or behavioral disability classified as ever diagnosed with attention deficit hyperactivity disorder (ADHD), autism or pervasive development disorder (PDD), oppositional defiant disorder (ODD), intellectual disability, stuttering or other developmental delay.

[d] Physical disability classified as ever diagnosed with hearing loss, blindness, epilepsy or mobility disability such as cerebral palsy.

[e] Models adjusted for all variables above and child weight status at kindergarten entry.

Table 4

Adjusted associations between maternal prepregnancy weight status and children's motor function at kindergarten entry, Early Childhood Longitudinal Study-Birth Cohort, United States, 2001-2007

Outcomes	Underweight (n = 350) RR (95% CI)	Normal weight (n = 2700) RR (95% CI)	Overweight (n = 1050) RR (95% CI)	Obese class I (n = 400) RR (95% CI)	Obese class II and III (n = 300) RR (95% CI)	P-value[a]
Adjusted for demographics, smoking and enrichment [b]						
Low fine motor[c]	0.62 (0.35, 1.11)	1.00 (Referent)	0.98 (0.65, 1.47)	1.47 (1.00, 2.17)	1.45 (0.84, 2.52)	0.06
Low gross motor[d]	1.28 (0.74, 2.22)	1.00 (Referent)	1.50 (1.10, 2.05)	1.33 (0.86, 2.05)	2.16 (1.54, 3.05)	<0.001
Adjusted for demographics, smoking, enrichment and current child weight status [e]						
Low fine motor[c]	0.59 (0.33, 1.08)	1.00 (Referent)	0.97 (0.63, 1.51)	1.29 (0.82, 2.03)	1.49 (0.85, 2.61)	0.12
Low gross motor[d]	1.32 (0.77, 2.26)	1.00 (Referent)	1.42 (1.01, 2.00)	1.09 (0.65, 1.84)	1.73 (1.16, 2.58)	0.05

Abbreviations: CI, confidence interval; RR, risk ratio.

[a] *P* for the overall adjusted association with prepregnancy weight status.

[b] Models adjusted for child's sex, age at final assessment, year of kindergarten entry, TV hours, number of children's books in the house and typical number of nights parent reads to the child, as well as maternal age, race-ethnicity, parity, schooling, poverty and smoking during pregnancy.

[c] Children who did not successfully pass the gate building assessment and at least half of the copy shape assessments were classified as having low fine motor function.

[d] Children who passed less than half of the gross motor tasks were classified as having low gross motor function.

[e] Models adjusted for all variables above and child weight status at kindergarten entry.

Table 5

Adjusted associations between maternal prepregnancy weight status and children's reading and math Z-scores at kindergarten entry, Early Childhood Longitudinal Study-Birth Cohort, United States, 2001-2007

	Underweight (n = 350) β (95% CI)	Normal weight (n = 2850) β (95% CI)	Overweight (n = 1150) β (95% CI)	Obese class I (n = 450) β (95% CI)	Obese class II and III (n = 300) β (95% CI)	p-value[a]
Adjusted for demographics, smoking and enrichment[b]						
Reading Z-score	–0.03 (–0.17,0.11)	0.00 (Referent)	–0.13 (–0.21, –0.05)	–0.14 (–0.27, –0.01)	–0.13 (–0.29, 0.02)	0.01
Math Z-score	–0.04 (–0.17, 0.08)	0.00 (Referent)	–0.07 (–0.15, 0.01)	–0.06 (–0.16, 0.04)	–0.14 (–0.27, –0.003)	0.11
Adjusted for demographics, smoking, enrichment and current child weight status[c]						
Reading *Z*-score	–0.03 (–0.17, 0.11)	0.00 (Referent)	–0.11 (–0.19, –0.03)	–0.14 (–0.27, –0.00)	–0.14 (–0.29, 0.02)	0.03
Math *Z*-score	–0.03 (–0.16, 0.09)	0.00 (Referent)	–0.06 (–0.13, 0.02)	–0.06 (–0.16, 0.04)	–0.14 (–0.29, 0.01)	0.19

Abbreviation: CI, confidence interval.

[a] P for the overall adjusted association with prepregnancy weight status.

[b] Models adjusted for child's sex, age at final assessment, year of kindergarten entry, TV hours, number of children's books in the house and typical number of nights parent reads to the child, as well as maternal age, race-ethnicity, parity, schooling, poverty and smoking during pregnancy.

[c] Models adjusted for all variables above and child weight status at kindergarten entry.